OGIP Calibration Memo CAL/GEN/92-020

THE OGIP FORMAT FOR RADIAL POINT SPREAD FUNCTION DATASETS

Ian M. George & Rehana Yusaf
Mail Code 668,
NASA/GSFC,
Greenbelt,
MD20771.

and

Michael F. Corcoran
CRESST & X-ray Astrophysics Lab
Code 662 NASA/GSFC, Greenbelt, MD20771
and
Universities Space Research Association
10211 Wincopin Circle, Columbia, MD 21044.

Version: 2011 Oct 21

SUMMARY

The document describes the standard formats adopted by the OGIP for the storage of the Radial Point Spread Function (RPSF) and Radial Encircled Energy Function (REEF) datasets, which describe the radial angular/spatial response of an instrument as a function of energy, and position.
Intended audience: primarily HEASARC programmers & hardware teams.

Log of Significant Changes

Release Date	Sections Changed	Brief Notes
1992 Jul 24	First Draft	(within memo CAL/GEN/92-003)
1993 Oct 03	All	Separation from CAL/GEN/92-003
1994 Jan 12	All	Revised & added HDUCLASn info
1995 Jan 19	All	Made compatible with LaTeX2HTML software
1995 Feb 10	All	Fixed typos & ambiguities
2011 Oct 20	All (and Appendix)	more typos; added Figure 1 and Appendix

Contents

1 Introduction **5**

1.1 Storage Options 6

1.2 Dataset Origins & Storage Recommendations 7

1.3 Dataset vs Task Summary 7

1.4 Software Considerations 7

2 RPSF Data File Formats **9**

2.1 Summary of RPSF file formats versions 9

2.2 The Radial PSF Extension (HDUVERS = '1.0.0') 11

3 REEF Data File Formats **17**

3.1 Summary of REEF file formats versions 17

3.2 The Radial Encircled Energy Fraction Extension (HDUVERS = '1.0.0') 19

4 Virtual File Formats & Allowed Standalone Tasks **25**

4.1 VCF Requirements 25

5 Related Software **26**

6 Example FITS headers **27**

6.1 *ROSAT* 27

6.2 *ASCA* 29

7 Appendix **32**

RELATED DOCUMENTATION

The following documents may also be of use:

- ***BCF & CPF Calibration File Guidelines***
  CAL/GEN/92-003 (George & Zellar)
- ***Calibration Index Files***
  CAL/GEN/92-008 (George, Pence & Zellar)
- ***Mandatory FITS Keywords for Calibration Files***
  CAL/GEN/92-011 (George, Zellar & Pence)
- ***Virtual Calibration Files***
  CAL/GEN/92-013 (George, Zellar & White)
- ***The OGIP format for 2-d PSFs***
  CAL/GEN/92-027 (George & Yusaf)

1 Introduction

Within the HEASARC CALDB the term *"Point Spread Function"* (*PSF*) (or *"Point Response Function"*, *PRF*) is used to refer to the spatial/angular spreading of incident photons from a point source caused by the instrument (mirror or optical system, and – optionally – the detector). In the most common and simple case, imperfections in the surface smoothness and shape of the mirrors result in incident photons from cosmic sources not being perfectly focussed on the focal plane. Thus the number of events detected as a function of position in the focal plane is not the idealized delta-function at the expected position, but has a characteristic shape (depending upon the optics and detectors in use) with a finite width. More generally, the *PSF* also can include spreading of events due to geometrical effects (*eg* obscuring structures, the detector surface not laying exactly on the focal plane, including coma), and effects within the detector (*eg* lateral charge-cloud drift in gas experiments), *etc.*

Thus, generally a point-source at infinity gives rise to a 2-dimensional image of finite size. Within the HEASARC CALDB such a dataset is refered to as a *2DPSF*, and the FITS file format for such calibration datasets are described in CAL/GEN/92-027 (George & Yusaf). In this memo we concentrate on *Radial Point Spread Functions* which give the source surface brightness as a function of radial distance from the focal point. These radial point spread functions represent the azimuthally-averaged values of the detected source surface brightness from a *2DPSF*, centered on the nominal point of focus assuming an idealized optical path. In practice, the centroid of the *2DPSF* is often used instead of the theoretical position of focus.

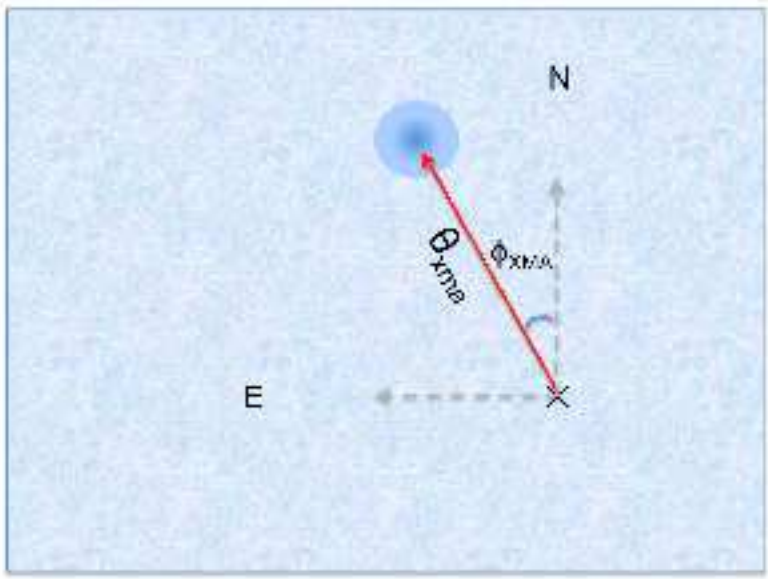

Figure 1: The detector plane in sky coordinates. *N* is to the top, *E* to the left. The optical axis is normal to the detector at the point marked by the ×, and the imaged source is represented by the blue circle. The off-axis angle θ_{XRA} and azimuthal angle ϕ_{XRA} are shown. The azimuthal angle ϕ_{XRA} is usually measured from north through east by convention.

The HEASARC CALDB currently recognizes two types of datasets relating to the storage of the radial point spread function of an instrument:

- ***Radial Point Spread Function*** (***RPSF***) datasets; each element of which essentially describes the probability of an event (which was successfully detected by the detector) being detected at a position which lies within a given annulus centered on the theoretical position of focus. The dataset is normalized to either a single event (giving the true probability per unit area for each annulus – the prefered method for calibration datasets), or a given number of "total" events (giving the expected/observed number of counts per unit area for each annulus – often useful for observational datasets).
- ***Radial Encircled Energy Function*** (***REEF***) datasets; each element of which describes the fraction of the 'total' events (when integrated out to a large/infinite radius) contained within circles of increasing radii centered on the theoretical position of focus.

Both the RPSF and REEF data historically have been referred to as *radial point spread functions*. However, for clarity, the HEASARC CALDB distinguishes the two.

Finally, it should be noted that for most instruments, the azimuthal averaging involved in their construction means that neither ***RPSF*** nor ***REEF*** (calibration datasets) are suitable for a detailed scientific investigation of the spatial extent of a detected source. Rather, both types of dataset provide:

- a "first-look" indication as to whether a given observational image is spatially extended beyond that expected due to the instrumental response, and/or
- a method of determining what fraction of the (source) counts lie within a given radius,
- the correction of detected count rate for the finite detect cell size to determine the total count rate,
- the region where the background starts to dominate over source counts,
- the requisite size of the "detection cell" to use to be most sensitive to detecting sources,
- *etc.*

Detailed image reconstruction of non-point-source targets should use full 2-dimensional ***RDPSF*** calibration datasets described in CAL/GEN/92-027 (George & Yusaf).

1.1 Storage Options

The point spread function in general depends on annular distance R from the point of focus, the incident photon energy E, and on the position of the point of focus on the detector, usually given in terms of two angles, the off-axis angle (θ_{XMA}) which accounts for the dependence of the ***RPSF*** on the angular distance from the optical axis, and an azimuthal angle (ϕ_{XMA}), as shown in figure 1. When stored in a FITS file, both ***RPSF*** and ***REEF*** datasets consist of a 4-dimensional grid, with 1 axis giving the "radius" (R, the angular distance from the theoretical

point of focus), 1 axis giving the photon energy (E), and 2 axes (θ_{XMA} and ϕ_{XMA}) defining the position relative to the optical axis at which each ***RPSF*** dataset is valid.

1.2 Dataset Origins & Storage Recommendations

The construction, format used (within the limitations discussed here) and delivery of the data to the HEASARC (including any updates) is the responsibility of the instrument team. However, below, are the recommendations of the HEASARC CALDB team based on our experience. Our emphasis is on "calibration" ***RPSF*** or ***REEF*** datasets (*ie* datasets which are likely to be used as "standard calibrations" by users and analysis software, and delivered to and stored in the HEASRAC CALDB). Consequently, a number of the issues discussed here and in the document as a whole are not applicable to datasets derived from non-calibration, Guest Observer observations.

General
In both the case of ***RPSF***s and ***REEF***s, use of virtual calibration files are recommended (see Sections 1.3 & 4) for those cases where the point spread function can be adequately described by simple functional forms (gaussians, lorentzians, *etc.*).

Pre-launch
Prior to launch, the spatial/angular spreading of a point source is measured at a (limited) number of positions and/or photon energies during ground calibrations and/or modelled analytical (*eg* by ray-tracing) to characterize the PSF. In most cases these results can be parameterized and stored in a virtual calibration file (Sections 1.3 & 4).

Post-launch
After launch, the pre-launch PSFs are usually checked and updated using a limited number of pointings of known bright point-sources (LMC X-1, Cyg X-3, ζ Pup, *etc.*) usually at a number of off-axis and azimuthal angles. Often the results from these observations can be parameterized such that a virtual calibration file (Sections 1.3 & 4) can be created.

1.3 Dataset vs Task Summary

It is often possible to parameterize both a ***RPSF*** and ***REEF*** dataset for a given science instrument. In these cases the RPSF and/or REEF information may often be economically stored as a virtual calibration file, and an associated standalone s/w task (see CAL/GEN/92-003). Wherever possible, this is recommended. Virtual calibration files are discussed in Section 4.

1.4 Software Considerations

Data Files:
In the case of both ***RPSF*** and ***REEF*** datasets, interpolation between the θ_{XMA},ϕ_{XMA} grid

points is usually required for comparison with a pointed observation. Most often, analysis software will use a simple 2-dimensional **linear** interpolation when calculating the ***RPSF/REEF*** between $\theta_{XRTA}, \phi_{XRTA}$ grid points. Thus the $\theta_{XRTA}, \phi_{XRTA}$ grid should be of sufficient resolution to enable this to be reasonable approximation.

As discussed in CAL/GEN/92-003, it is strongly recommended that the energy grid be of sufficient resolution such that interpolation of this parameter is not required. However, in cases where interpolation is required, as simple 1-dimensional linear interpolation may be performed, (which will clearly which may be inaccurate close to sharp spectral features (detector absorption edges, for example).

Virtual Files:
No specific issues.

2 RPSF Data File Formats

The HEASARC FITS Working Group (HFWG) Header-Data Unit (HDU) keywords and values for this type of dataset are:

- `HDUCLASS = 'OGIP'`
  - the name of the organization that defined this file format.
- `HDUDOC = 'CAL/GEN/92-020'`
  - the name of the document describing the format (*ie* this document)
- `HDUCLASn`
  - giving the HDUCLAS hierarchy for this format.
    - `HDUCLAS1 = 'RESPONSE'`
    - `HDUCLAS2 = 'EPRF'`
    - `HDUCLAS3 = (see below)`
    - `HDUCLAS4 = (see below)`

These are valid for all datasets described in this section, and should be present in the **header of the extension** containing the *RPSF* dataset.

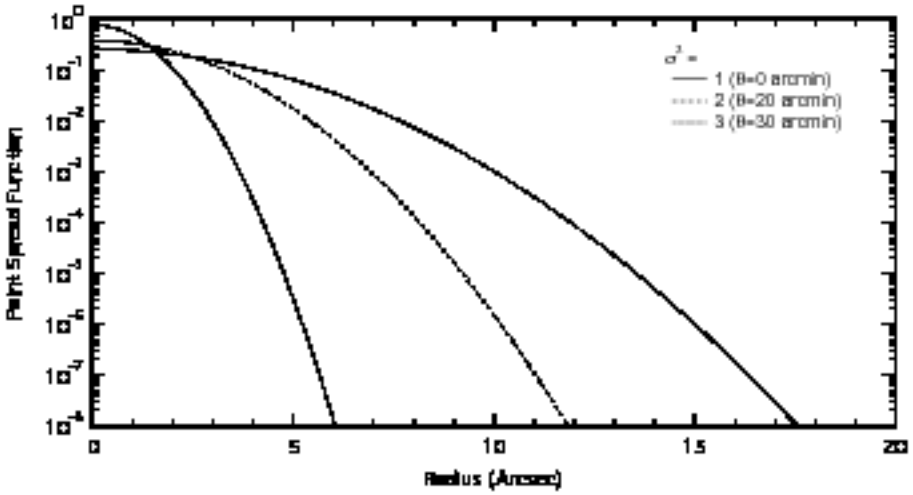

Figure 2: Plot of example radial point spread function. The PSFs shown are approximated as gaussians with given standard deviations σ values as shown. The PSFs broaden as the source off-axis angle increases. Each PSF is normalised to unity.

2.1 Summary of RPSF file formats versions

The following versions of file formats for a *RPSF* dataset have been defined:

- HDUVERS = '1.0.0' (Section 2.2)
  This format is currently still **VALID**.
  It was designed primarily for calibration datasets, but can be used for GO datasets.

2.2 The Radial PSF Extension (HDUVERS = '1.0.0')

Description:
One file for each telescope/instrument combination containing a single BINTABLE FITS extension. The BINTABLE only has a single row, using arrays for the 8 necessary columns.

Note: this format was formally known as RPSFVERS = '1992a', and is still occasionally refered to as such.

Extension Header
Beyond the standard FITS keywords required, and the HDU keywords/values given in Section 2, the following keywords/values are mandatory:

- TELESCOP - the name of the satellite/mission.
  Allowed values are given in CAL/GEN/92-011.
- INSTRUME - the name of the telescope mirror/detector assembly.
  Allowed values are given in CAL/GEN/92-011.
- HDUVERS = '1.0.0' - giving the version of the format.
- HDUCLAS3 - further describing the scientific content of the dataset, specifically regarding the origin of the dataset. The allowed values are:
  - HDUCLAS3 = 'OBSERVED' - indicating the ***RPSF*** dataset has been generated from an observational dataset.
  - HDUCLAS3 = 'PREDICTED' - indicating the ***RPSF*** has been generated using a theoretical model.
- HDUCLAS4 - further describing the scientific content of the dataset, specifically regarding the contents of the dataset. The allowed values are:
  - HDUCLAS4 = 'TOTAL' - indicating the ***RPSF*** dataset includes counts from the 'source' as well as any counts from the 'background'
  - HDUCLAS4 = 'NET' - indicating the ***RPSF*** dataset has been background-subtracted
- TDIM*nnn* - the number of elements and ordering (see CAL/GEN/92-003) of each multi-dimensional array.
  Only the RPSF, AREA_WGT & (if present) the RPSF_ERR columns here (with *nnn*=7,8 & 9 in the example below).
- *i*CTYP*nnn* - The axis labels for dimension *i* (*i* = 1, 2, 3, 4) of the RPSF, AREA_WGT & (if present) the EPSF_ERR columns. In the example given below, *nnn* = 7, 8 & 9 respectively, and
  - 1CTYP7 = 'SPATIAL_OFFSET'
  - 2CTYP7 = 'COORD-1'
  - 3CTYP7 = 'COORD-2'

  - 4CTYP7 = 'ENERGY'
  - 1CTYP8 = 'SPATIAL_OFFSET'
  - 2CTYP8 = 'COORD-1'
  - 3CTYP8 = 'COORD-2'
  - 4CTYP8 = 'ENERGY'
  - 1CTYP9 = 'SPATIAL_OFFSET'
  - 2CTYP9 = 'COORD-1'
  - 3CTYP9 = 'COORD-2'
  - 4CTYP9 = 'ENERGY'

  (see CAL/GEN/92-003 for further details).

- CREFnnn = The column referencing keyword for each multi-dimensional array.
  Only the RPSF, AREA_WGT & (if present) the RPSF_ERR columns here (with *nnn*=7,8 & 9 in the example below) giving:

  - CREF7 = '(RAD_LO:RAD_HI,THETA,PHI,ENERG_LO:ENERG_HI)'
  - CREF8 = '(RAD_LO:RAD_HI,THETA,PHI,ENERG_LO:ENERG_HI)'
  - CREF9 = '(RAD_LO:RAD_HI,THETA,PHI,ENERG_LO:ENERG_HI)'

  in the example below.

- CSYSNAME - the spatial coordinate system in use
  Allowed values are given in CAL/GEN/92-003)
  (CSYSNAME = 'XMA_POL' is assumed in the example below)

- PIXSIZE - the angular size of (one side) of the pixels in units of decimal degrees.

- BACKGND - the background count rate in units of counts per pixel (where the pixel size is definded by PIXSIZ). If no underlying instrument or cosmic background is expected, then a value of zero should be entered.

- ENERG_LO - the minimum energy (in keV) for which the the *RPSF* dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- ENERG_HI - the maximum energy (in keV) for which the the *RPSF* dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- CHANMIN - the minimum detector channel number for which the the *RPSF* dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- CHANMAX - the maximum detector channel number for which the the *RPSF* dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- CHANTYPE - the type of detector channels CHANMIN & CHANMAX are expressed in, with the allowed values:

  - CHANTYPE = 'PHA' - for 'raw' detector channels

  - CHANTYPE = 'PI' - for (corrected) 'Pulse Invariant' detector channels

- SUMRCTS - the sum of the raw counts 'under' the ***RPSF*** dataset. Essentially the value of this keyword can provide the 'normalization' of an observed dataset. It is **strongly** urged that the ***RPSF*** supplied to the HEASARC CALDB be normalized to 1 count (ie SUMRCTS = 1.0).

and the following keywords/values are mandatory for CIF purposes **ONLY** if the dataset is ever to be included as a calibration file within the HEASARC CALDB (see CAL/GEN/92-011):

- CCLSCOD1 - the OGIP class of this calibration file, with allowed values:
  - CCLSCOD1 = 'BCF' - for Basic Calibration datasets
  - CCLSCOD1 = 'CPF' - for Calibration Product datasets
- CDTPCOD1 - the OGIP class of the data type, with allowed values:
  - CDTPCOD1 = 'DATA' - for 'true' datasets
  - CDTPCOD1 = 'TASK' - for 'virtual' calibration datasets
- CCNMCOD1 = 'EPSF' - the OGIP codename for the contents
- CHDnDOD1 - the parameter-space limitations of the dataset (see below)
- CVSDCOD1 - calibration validity start date
- CVSTCOD1 - calibration validity start time
- CDESCOD1 - a descriptive string of the calibration dataset

and the following mandatory to supply further information:

- RPSFVERS = '1992a' - the OGIP version of the FITS format in use

Data Format:
The data within the extension is organised as a BINTABLE with the following columns:

1. R_{lo_i}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the lower radial bounds of the annular bins as measured from the nominal point of focus.
   The FITS column name is **RAD_LO**.
   The recommended units are arcmin.
2. R_{hi_i} a fixed-length REAL vector (array, each element within which is 4-byte) containing the upper radial bounds of the annular bins as measured from the nominal point of focus.
   The FITS column name is **RAD_HI**.
   The recommended units are arcmin.

3. θ_{XMA}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the off-axis angles.
   The FITS column name is **THETA** (but see below).
   The recommended units are arcmin.

4. ϕ_{XMA}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the azimuthal angles.
   The FITS column name is **PHI** (but see below).
   The recommended units are arcmin.

5. E_{low}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the lower energy bounds of the energy bins.
   The FITS column name is **ENERG_LO**.
   The recommended units are keV.

6. E_{high}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the upper energy bounds of the energy bins.
   The FITS column name is **ENERG_HI**
   The recommended units are keV.

7. $RPSF$, a fixed-length REAL vector (array, each element within which is 4-byte) containing the $RPSF$ measurement at each $R, \theta_{XMA}, \phi_{XMA}, E$ grid point.
   The FITS column name is **RPSF**.
   The order of data storage is $RPSF(R, \theta_{XMA}, \phi_{XMA}, E)$, where R & E represent the R_{low} and R_{high}, E_{low} and E_{high} arrays respectively (see below).
   The recommended units are per square arcmin.

8. A_{wgt}, a fixed-length REAL vector (array, each element within which is 4-byte) containing an area weighting factor at each $R, \theta_{XMA}, \phi_{XMA}, E$ grid point.
   The FITS column name is **AREA_WGT**.
   The order of data storage is $A_{wgt}(R, \theta_{XMA}, \phi_{XMA}, E)$, where R & E represent the R_{low} and R_{high}, E_{low} and E_{high} arrays respectively (see below).
   No units (dimensionless)

These are summarized in Table 1.

Points to Note & Conventions

- The ordering of the columns is of course arbitrary, however that used here is recommended.
- The rules and conventions concerning the energy grid (E_{low} & E_{high}) given in CAL/GEN/92-003 apply.
- An alternate spatial coordinate frame may be used, in which case
  - the values of the CSYS*nnn* keywords should be replaced by the appropriate string listed in CAL/GEN/92-003.

Table 1: Summary of the OGIP format for Radial PSFs (HDUVERS = 1.0.0).

Extension to *(filename).(ext)*

HDUCLASS: OGIP
HDUDOC: CAL/GEN/92-020
HDUVERS: 1.0.0
HDUCLAS1: RESPONSE
HDUCLAS2: RPRF
HDUCLAS3: *see text*
HDUCLAS4: *see text*
EXTNAME : RPSF (suggested, not required)
Description: Radial Point spread Function datasets (including errors, if required) as a function of radial angular distance from centroid, energy, off-axis & azimuthal angle.
An alternate spatial coordinate frame may also be used (see text).
Format: BINTABLE

column							
1	2	3	4	5	6	7	8
contents							
Inner Radius	**Outer Radius**	**Off-axis angles**	**Azimuthal angles**	**Low energy bounds**	**High energy bounds**	**Radial PSF data**	**Area Weighting**
R_{low}	R_{high}	θ_{OFFA}	ϕ_{AZMA}	E_{low}	E_{high}	*RPSF*	A_{wgt}
format of each column							
4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array
total number of elements per row							
i	*i*	*j*	*k*	*m*	*m*	*i* x *j* x *k* x *m*	*i* x *j* x *k* x *m*
column name							
RAD_LO	RAD_HI	THETA	PHI	ENERG_LO	ENERG_HI	RPSF	AREA_WGT

  - and/or (if necessary) the THETA & PHI column names replaced by more suitable alternatives if a different coordinate notation is employed. In this case the CSYSNAME keyword is mandatory and should give the column names used (see CAL/GEN/92-003).

  Spatial coordinate frames cannot be mixed within a given dataset.

- The parameter-space limitations on the dataset involving the following *pname* strings are recommended to be specified via the CBDn001 keywords (see CAL/GEN/92-003):

  - *pname* = THETA - giving the range of off-axis angle for which the dataset is valid;
  - *pname* = PHI - giving the range of azimuthal angle for which the dataset is valid;

  (or corresponding alternate values of *pname* if a different coordinate notation is employed) along with any other limitations the authors of the dataset consider necessary.

- Datasets in which $RPSF$ is independent of ϕ_{XRTA} (or θ_{XRTA}) should contain PHI = 0.0 (or THETA = 0.0) as a header keyword (or a corresponding alternate keyword if a different coordinate notation is employed).

- Alternative physical units are allowed for all columns of the table as long as they conform to the rules given in OGIP/93-001. The same is true for the physical units associated with the CBDn001 keywords.

- The order of $RPSF(Rad, \theta_{XRTA}, \phi_{XRTA}, E)$ whereby the radial parameters change fastest, and the energy parameters slowest was chosen to facilitate access for the most common applications: interpolation in $\theta_{XRTA}, \phi_{XRTA}$-space of $RPSF$ vs R_{Low}, R_{High} arrays. This ordering is further confirmed by the value of the mandatory TDIMnnn keyword for this array (where nnn = 7 in the above example).

- An optional array containing the 1σ statistical error associated with each element of $RPSF$ (if required) should be contained in an additional column named **RPSF_ERR**.

3 REEF Data File Formats

The HEASARC FITS Working Group (HFWG) Header-Data Unit (HDU) keywords and values for this type of dataset are:

- `HDUCLASS = 'OGIP'`
  - the name of the organization that defined this file format.
- `HDUDOC = 'CAL/GEN/92-020'`
  - the name of the document describing the format (*ie* this document)
- `HDUCLASn`
  - giving the HDUCLAS hierarchy for this format.
    - `HDUCLAS1 = 'RESPONSE'`
    - `HDUCLAS2 = 'REEF'`
    - `HDUCLAS3 = (see below)`
    - `HDUCLAS4 = (see below)`

These are valid for all datasets described in this section, and should be present in the **header of the extension** containing the ***REEF*** dataset.

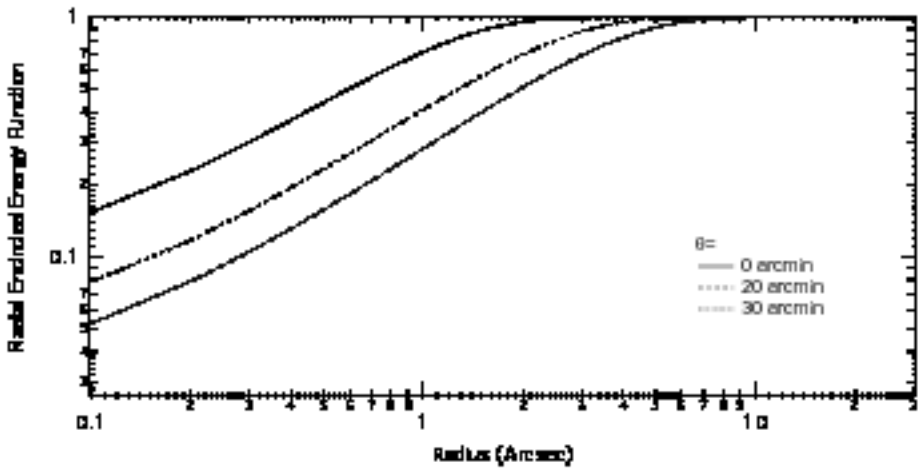

Figure 3: Plot of sample radial encircled energy function. The REEFs shown are approximated as gaussians with standard deviations σ given as in Figure 2 above. Because the PSFs broaden as the source off-axis angle increases, an extraction cell of a given size captures less of the integrated flux as the source is placed at increasingly larger off-axis positions.

3.1 Summary of REEF file formats versions

The following versions of file formats for a ***REEF*** dataset have been defined:

- HDUVERS = '1.0.0' (Section 3.2)
  This format is currently still **VALID**.
  It was designed primarily for calibration datasets, but can be used for GO datasets.

3.2 The Radial Encircled Energy Fraction Extension (HDUVERS = '1.0.0')

Description:
One file for each telescope/instrument combination containing a single BINTABLE FITS extension. The BINTABLE only has a single row, using arrays for the 8 necessary columns.

Note: this format was formally known as REEFVERS = '1992a', and is still occasionally refered to as such.

Extension Header
Beyond the standard FITS keywords required, and the HDU keywords/values given in Section 3, the following keywords/values are mandatory:

- TELESCOP - the name of the satellite/mission.
  Allowed values are given in CAL/GEN/92-011.
- INSTRUME - the name of the telescope mirror/detector assembly.
  Allowed values are given in CAL/GEN/92-011.
- HDUVERS = '1.0.0' - giving the version of the format.
- HDUCLAS3 - further describing the scientific content of the dataset, specifically regarding the origin of the dataset. The allowed values are:
  - HDUCLAS3 = 'OBSERVED' - indicating the ***RPSF*** dataset has been generated from an observational dataset.
  - HDUCLAS3 = 'PREDICTED' - indicating the ***RPSF*** has been generated using a theoretical model.
- HDUCLAS4 - further describing the scientific content of the dataset, specifically regarding the contents of the dataset. The allowed values are:
  - HDUCLAS4 = 'TOTAL' - indicating the ***RPSF*** dataset includes counts from the 'source' as well as any counts from the 'background'
  - HDUCLAS4 = 'NET' - indicating the ***RPSF*** dataset has been background-subtracted
- TDIM*nnn* - the number of elements and ordering (see CAL/GEN/92-003) of each multi-dimensional array.
  Only the REEF & AREA_WGT columns here (with *nnn* = 7,8 in the example below).
- *i*CTYP*nnn* - The axis labels for dimension *i* (*i* = 1, 2, 3, 4) of the REEF & AREA_WGT columns. In the example given below, *nnn* = 7 & 8 respectively, and
  - 1CTYP7 = 'SPATIAL_OFFSET'
  - 2CTYP7 = 'COORD-1'
  - 3CTYP7 = 'COORD-2'
  - 4CTYP7 = 'ENERGY'
  - 1CTYP8 = 'SPATIAL_OFFSET'

  - 2CTYP8 = 'COORD-1'
  - 3CTYP8 = 'COORD-2'
  - 4CTYP8 = 'ENERGY'

  (see CAL/GEN/92-003 for further details).

- CREFnnn = The column referencing keyword for each multi-dimensional array.
  Only the REEF & AREA_WGT columns here (with nnn=7 & 8 in the example below) giving:

  - CREF7 = '(RAD_LO:RAD_HI,THETA,PHI,ENERG_LO:ENERG_HI)'
  - CREF8 = '(RAD_LO:RAD_HI,THETA,PHI,ENERG_LO:ENERG_HI)'

  in the example below.

- CSYSNAME - the spatial coordinate system in use
  Allowed values are given in CAL/GEN/92-003.
  (CSYSNAME = 'XMA_POL' is assumed in the example below)

- PIXSIZE - the angular size of (one side) of the pixels in units of decimal degrees.

- BACKGND - the background count rate in units of counts per pixel (where the pixel size is definded by PIXSIZ). If no underlying instrument or cosmic background is expected, then a value of zero should be entered.

- ENERG_LO - the minimum energy (in keV) for which the the ***REEF*** dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- ENERG_HI - the maximum energy (in keV) for which the the ***REEF*** dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- CHANMIN - the minimum detector channel number for which the the ***REEF*** dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- CHANMAX - the maximum detector channel number for which the the ***REEF*** dataset was constructed or is valid. The value -99.0 indicates that the value is unknown.

- CHANTYPE - the type of detector channels CHANMIN & CHANMAX are expressed in, with the allowed values:

  - CHANTYPE = 'PHA' - for 'raw' detector channels
  - CHANTYPE = 'PI' - for (corrected) 'Pulse Invariant' detector channels

and the following keywords/values are mandatory for CIF purposes **ONLY** if the dataset is ever to be included as a calibration file within the HEASARC CALDB (see CAL/GEN/92-011):

- CCLS0001 - the OGIP class of this calibration file, with allowed values:

  - CCLS0001 = 'BCF' - for Basic Calibration datasets

  - CCLSCCD1 = 'CPF' - for Calibration Product datasets

- CDTPCCD1 - the OGIP class of the data type, with allowed values:
  - CDTPCCD1 = 'DATA' - for 'true' datasets
  - CDTPCCD1 = 'TASK' - for 'virtual' calibration datasets
- CCNMCCD1 = 'REEF' - the OGIP codename for the contents
- CHDnCCD1 - the parameter-space limitations of the dataset (see below)
- CVSDCCD1 - calibration validity start date
- CVSTCCD1 - calibration validity start time
- CDESCCD1 - a descriptive string of the calibration dataset

and the following mandatory to supply further information:

- REEFVERS = '1992a' - the OGIP version of the FITS format in use

Data Format:
The data within the extension is organised as a BINTABLE with the following columns:

1. R_{low}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the lower radial bounds of the annular bins as measured from the nominal point of focus.
   The FITS column name is **RAD_LO**.
   The recommended units are arcmin.
2. R_{high}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the upper radial bounds of the annular bins as measured from the nominal point of focus.
   The FITS column name is **RAD_HI**.
   The recommended units are arcmin.
3. θ_{XMA}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the off-axis angles.
   The FITS column name is **THETA** (but see below).
   The recommended units are arcmin.
4. ϕ_{XMA}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the azimuthal angles.
   The FITS column name is **PHI** (but see below).
   The recommended units are arcmin.
5. E_{low}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the lower energy bounds of the energy bins.
   The FITS column name is **ENERG_LO**.
   The recommended units are keV.

6. E_{high}, a fixed-length REAL vector (array, each element within which is 4-byte) containing the upper energy bounds of the energy bins.
   The FITS column name is **ENERG_HI**.
   The recommended units are keV.

7. ***REEF***, a fixed-length REAL vector (array, each element within which is 4-byte) containing the ***REEF*** measurement at each $R, \theta_{XMA}, \phi_{XMA}, E$ grid point.
   The FITS column name is **REEF**.
   The order of data storage is $REEF(R, \theta_{XMA}, \phi_{XMA}, E)$, where R & E represent the R_{low} and R_{high}, E_{low} and E_{high} arrays respectively (see below).
   No units (dimensionless)

8. A_{wgt}, a fixed-length REAL vector (array, each element within which is 4-byte) containing an area weighting factor at each $R, \theta_{XMA}, \phi_{XMA}, E$ grid point.
   The FITS column name is **AREA_WGT**.
   The order of data storage is $A_{wgt}(R, \theta_{XMA}, \phi_{XMA}, E)$, where R & E represent the R_{low} and R_{high}, E_{low} and E_{high} arrays respectively (see below).
   No units (dimensionless)

These are summarized in Table 2.

Points to Note & Conventions

- The ordering of the columns is of course arbitrary, however that used here is recommended.
- The rules and conventions concerning the energy grid (E_{low} & E_{high}) given in CAL/GEN/92-003 apply.
- An alternate spatial coordinate frame may be used, in which case
  - the values of the CSYSmmm keywords should be replaced by the appropriate string listed in CAL/GEN/92-003.
  - and/or (if necessary) the THETA & PHI column names replaced by more suitable alternatives if a different coordinate notation is employed. In this case the CSYSNAME keyword is mandatory and should give the column names used (see CAL/GEN/92-003).

  Spatial coordinate frames cannot be mixed within a given dataset.
- The parameter-space limitations on the dataset involving the following *pname* strings are recommended to be specified via the CDnn0001 keywords (see CAL/GEN/92-003):
  - *pname* = THETA - giving the range of off-axis angle for which the dataset is valid;
  - *pname* = PHI - giving the range of azimuthal angle for which the dataset is valid;

  (or corresponding alternate values of *pname* if a different coordinate notation is employed) along with any other limitations the authors of the dataset consider necessary.

Table 2: Summary of the OGIP format for Radial EEFs (REEFVERS = 1992a).

Extension to *(filename).(ext)*

HDUCLASS: OGIP
HDUDOC: CAL/GEN/92-020
HDUVERS: 1.0.0
HDUCLAS1: RESPONSE
HDUCLAS2: REEF
HDUCLAS3: *see text*
HDUCLAS4: *see text*
EXTNAME : REEF (suggested, not required)
Description: Radial Encircled Energy Function datasets (including errors, if required) as a function of radial angular distance from centroid, energy, off-axis & azimuthal angle.
An alternate spatial coordinate frame may also be used (see text).
Format: BINTABLE

column							
1	2	3	4	5	6	7	8
contents							
Inner Radius	**Outer Radius**	**Off-axis angles**	**Azimuthal angles**	**Low energy bounds**	**High energy bounds**	**Radial PSF data**	**Area Weighting**
R_{low}	R_{high}	θ_{OAA}	ϕ_{AZA}	E_{low}	E_{high}	*REEF*	A_{wgt}
format of each column							
4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array	4-byte real array
total number of elements per row							
i	*i*	*j*	*k*	*m*	*m*	*i x j x k x m*	*i x j x k x m*
column name							
RAD_LO	RAD_HI	THETA	PHI	ENERG_LO	ENERG_HI	REEF	AREA_WGT

- Datasets in which $\boldsymbol{REEF}$ is independent of $\boldsymbol{\phi_{XRTA}}$ (or $\boldsymbol{\theta_{XRTA}}$) should contain PHI = 0.0 (or THETA = 0.0) as a header keyword (or a corresponding alternate keyword if a different coordinate notation is employed).

- Alternative physical units are allowed for all columns of the table as long as they conform to the rules given in OGIP/93-001. The same is true for the physical units associated with the CHDnOOOl keywords.

- The order of $\boldsymbol{REEF(Rad, \theta_{XRTA}, \phi_{XRTA}, E)}$ whereby the radial parameters change fastest, and the energy parameters slowest was chosen to facilitate access for the most common applications: interpolation in $\boldsymbol{\theta_{XRTA}, \phi_{XRTA}}$-space of $\boldsymbol{RPSF}$ vs $\boldsymbol{R_{low}, R_{high}}$ arrays. This ordering is further confirmed by the value of the mandatory TDIMnnn keyword for this array (where nnn = 7 in the above example).

- An optional array containing the 1σ statistical error associated with each element of $\boldsymbol{RPSF}$ (if required) should be contained in an additional column named **REEF_ERR**.

4 Virtual File Formats & Allowed Standalone Tasks

Standalone tasks to perform the following tasks are currently allowed:

- Calculate the Radial Point Spread Function, $RPSF(R, \theta_{XMA}, \phi_{XMA}, E)$ as a function of radius from the nominal point of focus (R), for a given off-axis position θ_{XMA},ϕ_{XMA} and (range of) photon energy (E).
  Output:
  The format of the o/p file should be one of the allowed data formats given in Section 2.
  Notes:
  None
- Calculate the Radial Encircled Energy Fraction, $REEF(R, \theta_{XMA}, \phi_{XMA}, E)$ as a function of radius from the nominal point of focus (R), for a given off-axis position θ_{XMA},ϕ_{XMA} and (range of) photon energy (E).
  Output:
  The format of the o/p file should be one of the allowed data formats given in Section 3.
  Notes:
  None

4.1 VCF Requirements

Description:
See CAL/GEN/92-003 & CAL/GEN/92-013. *Extension Header*
Beyond the standard FITS keywords required, the following keywords/values are mandatory:

- CSYSnnnn - the spatial coordinate system used by the standalone task

along (if desired) with those keywords/values mandatory for CIF purposes as given in within the appropriate sub-section of Sections 2 & 3, with the exception of:

- CDTP0001 (=TASK) - the OGIP class of the data type

plus those required for all virtual files listed in CAL/GEN/92-013, and the following mandatory keyword to supply further information:

- VIRVERSN - the OGIP version of the virtual FITS format in use (in this case 1992a)

Data Format:
See CAL/GEN/92-003 and CAL/GEN/92-013. The number and type of parameters specified depends solely on the requirements of the associated standalone task.

5 Related Software

The following list of subroutines/tasks are available:

- FORTRAN subroutine `wt???.f` (callib)
  writes an RPSFVERS = 1992a dataset (Section 2.2)

6 Example FITS headers

Here we give an example of keywords used in files currently within the CALDB.

6.1 *ROSAT*

Example 1

WARNING: This dataset has a number of keywords missing.

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  200 / width of table in bytes
NAXIS2  =                    1 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    5 / number of fields in each row
TTYPE1  = 'RAD_LO  '           / label for field   1
TFORM1  = '1GE     '           / data format of the field: 4-byte REAL
TUNIT1  = 'arcmin  '           / physical unit of field
TTYPE2  = 'RAD_HI  '           / label for field   2
TFORM2  = '1GE     '           / data format of the field: 4-byte REAL
TUNIT2  = 'arcmin  '           / physical unit of field
TTYPE3  = 'EPSF    '           / label for field   3
TFORM3  = '1GE     '           / data format of the field: 4-byte REAL
TUNIT3  = 'count/arcmin**2'    / physical unit of field
TTYPE4  = 'EPSF_ERR'           / label for field   4
TFORM4  = '1GE     '           / data format of the field: 4-byte REAL
TUNIT4  = 'count/arcmin**2'    / physical unit of field
TTYPE5  = 'AREA_WGT'           / label for field   5
TFORM5  = '1GE     '           / data format of the field: 4-byte REAL
EXTNAME = 'CHS EPSF'           / name of this binary table extension
TDIM1   = '(10)    '           /  Column dimension
TDIM2   = '(10)    '           /  Column dimension
TDIM3   = '(10,1,1)'           /  Column dimension
TDIM4   = '(10,1,1)'           /  Column dimension
TDIM5   = '(10,1,1)'           /  Column dimension
TELESCOP= 'ROSAT   '           / Name of Mission/Telescope
INSTRUME= 'PSPCB   '           / Name of Instrument/Detector
HDUCLASS= 'OGIP    '           / format conforms to OGIP standard
HDUCLAS1= 'RESPONSE'           / dataset is a response function
HDUCLAS2= 'EPRF    '           / dataset is a radial point response function
```

```
HDUCLAS3= 'NET     '           / Source only radial point spread function
HDUVERS1= '1.0.0   '           / Version of family of formats
HDUVERS2= '1.0.1   '           / Version of format
EPSFVER = '1993a   '           / OGIP FITS format version
THETA_LO=      -9.00000000E+01 / Value not defined
THETA_HI=      -9.00000000E+01 / Value not defined
ENERG_LO=      -9.00000000E+01 / Value not defined
ENERG_HI=      -9.00000000E+01 / Value not defined
DATE    = '14/04/94'           / FITS file creation date (dd/mm/yy)
HISTORY   ST2RPSF converts from STW -> RPSF format
HISTORY   STW FILE : pros2_3b_cnt.fits
HISTORY   EXTENSION WRITTEN BY WTEPF1 Ver 1.0.1
CREATOR = 'ST2RPSF 1.0.5'      / s/w task which wrote this dataset
PIXSIZE =           1.3888E-04 / In decimal degrees
BACKGRND=       0.00000000E+00 / In counts per pixel
CHANMIN =                   20 / Minimum PI channel for image
CHANMAX =                  100 / Maximum PI channel for image
SUMRCTS =         1.4869365E+04 / Sum of raw counts
END
```

Example 2

WARNING: This dataset has a number of keywords missing.

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  120 / width of table in bytes
NAXIS2  =                    1 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    5 / number of fields in each row
TTYPE1  = 'RAD_LO  '           / label for field   1
TFORM1  = '6E      '           / data format of the field: 4-byte REAL
TUNIT1  = 'arcmin  '           / physical unit of field
TTYPE2  = 'RAD_HI  '           / label for field   2
TFORM2  = '6E      '           / data format of the field: 4-byte REAL
TUNIT2  = 'arcmin  '           / physical unit of field
TTYPE3  = 'EPSF    '           / label for field   3
TFORM3  = '6E      '           / data format of the field: 4-byte REAL
TUNIT3  = 'count/arcmin**2'    / physical unit of field
TTYPE4  = 'EPSF_ERR'           / label for field   4
TFORM4  = '6E      '           / data format of the field: 4-byte REAL
TUNIT4  = 'count/arcmin**2'    / physical unit of field
TTYPE5  = 'AREA_WGT'           / label for field   5
```

```
TFORM6  = '6E      '           / data format of the field: 4-byte REAL
EXTNAME = 'CHS EPSF'           / name of this binary table extension
TDIM1   = '(6)     '           /  Column dimension
TDIM2   = '(6)     '           /  Column dimension
TDIM3   = '(6,1,1) '           /  Column dimension
TDIM4   = '(6,1,1) '           /  Column dimension
TDIM5   = '(6,1,1) '           /  Column dimension
TELESCOP= 'ROSAT   '           / Name of Mission/Telescope
INSTRUME= 'PSPCB   '           / Name of Instrument/Detector
HDUCLASS= 'OGIP    '           / format conforms to OGIP standard
HDUCLAS1= 'RESPONSE'           / dataset is a response function
HDUCLAS2= 'EPRF    '           / dataset is a radial point response function
HDUCLAS3= 'NET     '           / Source only radial point spread function
HDUVERS1= '1.0.0   '           / Version of family of formats
HDUVERS2= '1.0.1   '           / Version of format
EPSFVER = '1993a   '           / OGIP FITS format version
THETA_LO=      -9.00000000E+01 / Value not defined
THETA_HI=      -9.00000000E+01 / Value not defined
ENERG_LO=      -9.00000000E+01 / Value not defined
ENERG_HI=      -9.00000000E+01 / Value not defined
DATE    = '18/10/94'           / FITS file creation date (dd/mm/yy)
HISTORY   EXTENSION WRITTEN BY WTEPF1 Ver 1.0.1
COMMENT   DATA OBTAINED FROM RADIAL PROFILE : pros2_3b_cnt.st
COMMENT   THE RADIAL PROFILE DATA IS REBINNED
COMMENT   USING (USER DEFINED) MINIMUM COUNTS/BIN :    20.
COMMENT   LAST BIN CONTAINS LESS THAN MINIMUM COUNTS/BIN
COMMENT   WARNING : INPUT DATASET CONTAINS NEGATIVE COUNTS
PIXSIZE =         1.388900E-04 / pixelsize in deg
BACKGRND=         0.000000E+00 / Background count rate in cts/pixel
CHANMIN =                   10 / Minimum PI channel for image
CHANMAX =                  200 / Maximum PI channel for image
SUMRCTS =         1.486936E+04 / Sum of raw counts
CREATOR = 'EBNRPSF 1.1.1'      / s/w task which wrote this dataset
END
```

6.2 *ASCA*

Example 1

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =               733D64 / width of table in bytes
NAXIS2  =                    1 / number of rows in table
```

```
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    7 / number of fields in each row
TTYPE1  = 'RAD_LO  '           / label for field   1
TFORM1  = '50E     '           / data format of the field: 4-byte REAL
TUNIT1  = 'arcmin  '           / physical unit of field
TTYPE2  = 'RAD_HI  '           / label for field   2
TFORM2  = '50E     '           / data format of the field: 4-byte REAL
TUNIT2  = 'arcmin  '           / physical unit of field
TTYPE3  = 'THETA   '           / label for field   3
TFORM3  = '11E     '           / data format of the field: 4-byte REAL
TUNIT3  = 'arcmin  '           / physical unit of field
TTYPE4  = 'PHI     '           / label for field   4
TFORM4  = '3E      '           / data format of the field: 4-byte REAL
TUNIT4  = 'deg     '           / physical unit of field
TTYPE5  = 'ENERG_LO'           / label for field   5
TFORM5  = '11E     '           / data format of the field: 4-byte REAL
TUNIT5  = 'keV     '           / physical unit of field
TTYPE6  = 'ENERG_HI'           / label for field   6
TFORM6  = '11E     '           / data format of the field: 4-byte REAL
TUNIT6  = 'keV     '           / physical unit of field
TTYPE7  = 'EPSF    '           / label for field   7
TFORM7  = '18225E  '           / data format of the field: 4-byte REAL
TUNIT7  = '        '           / physical unit of field
EXTNAME = 'ASCA_PSF'           / name of this binary table extension
TDIM7   = '(50,11,3,11)'       /  Column dimension
1CTYP7  = 'SPATIAL_OFFSET'     /  Axis label
2CTYP7  = 'COORD-1 '           /  Axis label
3CTYP7  = 'COORD-2 '           /  Axis label
4CTYP7  = 'ENERGY  '           /  Axis label
CREF7   = '(RAD_LO:RAD_HI,THETA,PHI,ENERG_LO:ENERG_HI)' /  Column referencing
TELESCOP= 'ASCA    '           / Name of Mission/Telescope
CSYSNAME= 'XMA_POL '           / The spatial coordinate system in use
PIXSIZE =       8.18500004E-04 / The pixel size in decimal degrees
BACKGRND=       0.00000000E+00 / The background count rate in counts/pixs
SUMRCTS =                  1.0 / Sum of counts within a 6 arcmin radius
INSTRUME= 'XRT     '           / Name of Instrument/Detector
HDUCLASS= 'OGIP    '           / format conforms to OGIP standard
HDUCLAS1= 'RESPONSE'           / dataset is a response function
HDUCLAS2= 'EPRF    '           / dataset is a radial point response function
HDUCLAS3= 'PREDICTED'          / Predicted (theoretical) dataset
HDUCLAS4= 'NET     '           / Source only radial point spread function
HDUVERS1= '1.0.0   '           / Version of family of formats
HDUVERS2= '1.0.1   '           / Version of format
AREA_WGT=       1.00000000E+00 / Area Weighting Factor
DATE    = '19/09/95'           / FITS file creation date (dd/mm/yy)
```

```
HISTORY   EXTENSION WRITTEN BY WTEPF1 Ver 1.1.0
HDUDOC  = 'CAL/GEN/92-020'      / OGIP memo for File Format definition
EPSFVERS= '1992a   '            / OGIP FITS format version
CCLS0001= 'BCF     '            / OGIP class for this dataset
CCNM0001= 'EPSF    '            / OGIP codename for this dataset
CDTP0001= 'DATA    '            / OGIP datatype for this dataset
CVSD0001= '20/02/93'            / Date when data becomes valid
CVST0001= '02:00:00'            / Time when data becomes valid
CDES0001= 'XRT Radial Point-Spread-Function dataset from Nagoya ray-tracing' /
CHD10001= 'THETA(0,25)arcmin'   /
CHD20001= 'PHI(0,45)deg'        /
CHD30001= 'ENERG(1,10)keV'      /
END
```

REFERENCES

Information regarding on-line versions of any of the following references with an OGIP Memo number (i.e., documents starting OGIP/... or CAL/...) can most easily be found via the WorldWide Web by following the links from the URL http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/caldb_docs_index.html

Most OGIP Calibration Memos of general community interest have appeared as articles in the HEASARC journal *Legacy*.

George, I.M., 1992. *Legacy*, **1**, 56
(CAL/GEN/91-001)

George, I.M. & Zeller, R.E., 1992.
(CAL/GEN/92-003)

George, I.M., Zeller, R.E. & Pence, W., 1992.
(CAL/GEN/92-011)

George, I.M., Arnaud, K.A., Pence, W. & Ruamsuwan, L., 1992a.
(CAL/GEN/92-002)

George, I.M., *et al.*, 1992b.
(CAL/SW/92-004)

USEFUL LINKS TO OTHER HTML PAGES

The following links may be useful:

- The HEASARC: http://heasarc.gsfc.nasa.gov
- The CALDB home page: http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb
- The OGIP/HEASARC FITS Working Group Page: http://heasarc.gsfc.nasa.gov/docs/heasarc/ofwg/ofwg_intro.html
- The HEASARC FITS Conventions: http://heasarc.gsfc.nasa.gov/docs/heasarc/ofwg/ofwg_recomm.html

7 Appendix

Table 3: Sample PRF and REEF files

TELESCOP	INSTRUME	HDUCLASS	HDUCLASn	Location
CHANDRA	HRMA	ASC	HDUCLAS1= 'RESPONSE' HDUCLAS2= 'PSF ' HDUCLAS3= 'WPSF '	hrmaD1996-11-01wpsfN0001.fits
CHANDRA	HRMA		HDUCLAS1= 'RESPONSE' HDUCLAS2= 'REEF2 ' HDUCLAS3= 'PREDICTED' HDUCLAS4= 'NET '	hrmaD1996-12-20reefN0001.fits
CHANDRA	ACIS	ASC	HDUCLAS1= 'RESPONSE' HDUCLAS2= 'PSF ' HDUCLAS3= '2DPSF '	acis1998-11-05?dpsf1N0002.fits
CHANDRA	HRC	ASC	HDUCLAS1= 'RESPONSE' HDUCLAS2= 'PSF ' HDUCLAS3= '2DPSF '	hrc1998-11-05?dpsf1N0002.fits
Swift Swift	XRT XRT			swxpsf20010101v004.fits swxreef20010101v001.fits
Suzaku	XRT-I0			as_xrt0_psf_20090605.fits
Fermi	LAT	OGIP	HDUCLAS1= 'RESPONSE' HDUCLAS2= 'RPSF ' HDUVERS = '1.0.0 '	psf_P6_v11_diff_front.fits